Coriolis feeder with feed gate

Applying Coriolis

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Accurate weighing and feeding of pulverised coal, petcoke, and other additives is essential for the production of high quality cement. High accuracy, repeatability, reliability, and simplicity are some of the requirements of these weighing and feeding systems. A mass flow measuring system utilising the Coriolis principle is now available for these tasks. Practical applications of this technology for the cement industry will be discussed and data from several installations will show the benefits realized.

The Coriolis measuring principle was developed by carefully studying the science of particle acceleration and its resultant forces. The Coriolis force is the force that acts upon a particle accelerating radially outward in a rotating system. This force acts perpendicular to the direction of motion of the particle and is directly proportional to the torque required to accelerate that particle to the circumferential velocity of the rotating system. As seen below and in Figure 1, the Coriolis force is also directly proportional to the mass flow rate of a continuous stream of such particles. It is also significant to note that the relationship of the Coriolis force and the mass flow rate of the particles is independent of most process variables including the bulk density, friction coefficient, and moisture content of the particles.

Coriolis mass flow meter

The Coriolis measuring principle provides a simplified solution to mass flow measurement in industrial process applications. Figure 2 shows an internal view of the Coriolis mass flow meter, which consists of a rotating measuring wheel with several vertical guide vanes surrounding a central deflection cone. The measuring wheel is mounted on a drive shaft, which extends upwards from the deflection cone. These components are housed in a dust-tight enclosure. The shaft is driven by a swivel-mounted electric motor located above and outside the enclosure. This motor is connected to an electronic force measuring system (load cell) capable of determining the instantaneous torque delivered to the drive shaft. An off-centre feed inlet above one side of the wheel and a central outlet below the wheel provides the flow path for the bulk solid to be measured.

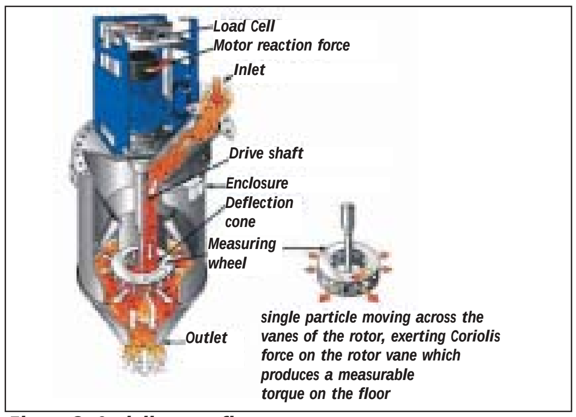
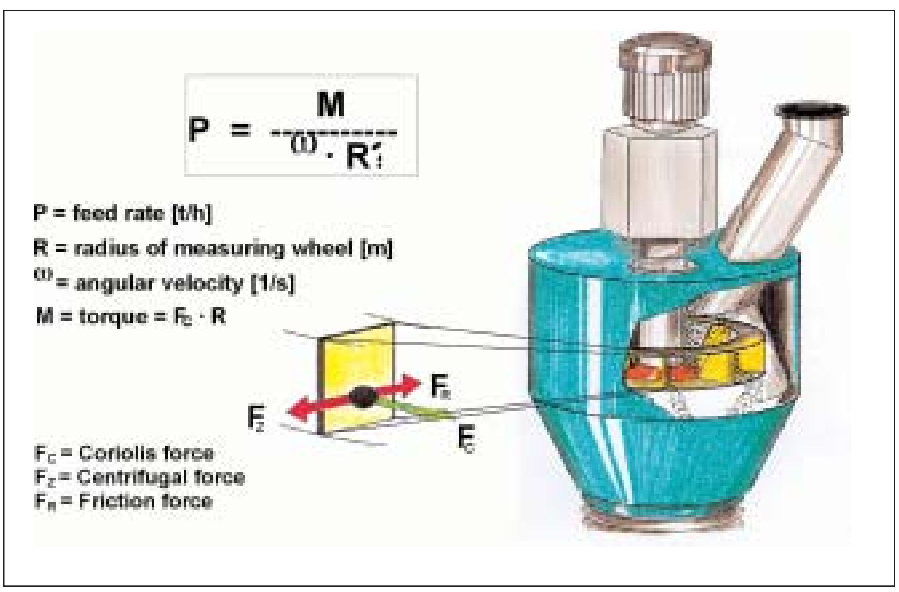


Figure 2: Coriolis mass flow meter

Figure 1: Coriolis measuring principle



In operation, the motor of the mass flow meter drives the shaft causing the measuring wheel to rotate at a constant angular velocity. Material flows downward through the inlet into the top of the wheel and the deflection cone diverts the particles outward in the radial direction. As the particles move along the vertical guide vanes, they are accelerated in the circumferential direction. As shown in Figure 1, the rotation of the measuring wheel causes

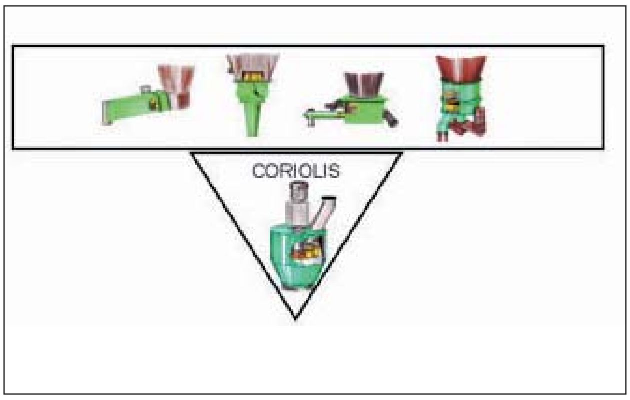


Figure 3: Coriolis feeding system – pre-feed devices

three forces – centrifugal, frictional, and Coriolis – to act on the particles as they move along the guide vanes.

- the centrifugal force acts in the radial direction
- the frictional force acts in the opposite direction with a magnitude equal to the centrifugal force
- the Coriolis force acts in the tangential direction and produces a measurable reaction torque in the measuring wheel's rotation that is directly proportional to the mass flow rate Microprocessor-based electronics analyse this torque signal and continuously compute the instantaneous material flow rate. A speed sensor is also incorporated into the system to precisely monitor the angular velocity of the measuring wheel.

The following discussion[1] illustrates the mathematical relationship of the relevant system variables:

The drive input into the drive shaft is equal to the energy imparted to the material as it passes over the guide vanes:

$$E = \int M * \omega * dt = \int dE$$

Where *E* is the energy imparted to the material, *M* is the drive torque, ω is the angular velocity, dt is time, and *dE* is the change in energy.

The energy required to move a particle with the mass *dP* out of the measuring wheel is:

$$dE = dP * \omega^2 * R^2$$

Where R is the radius of the measuring wheel.

From these equations, it follows that the drive torque M can be measured as:

$$M = P * \omega * R^2$$

Where *P* is the mass flow rate.

As these equations show, *M*, which depends on the Coriolis force, is directly proportional to the mass flow rate *P*. Thus, by measuring the torque, the Coriolis mass flow meter accurately measures the mass flow rate.

This measuring technique assures that frictional forces between the material and the measuring wheel or between different layers of material do not influence the mass flow measurement. In addition, the physical properties of the material, including density, friction and impact coefficients, particle size, and moisture content do not influence the accuracy or sensitivity of the meter. Variations in flow rate within a specified range have no influence on the measurement, ensuring that the measuring results are highly repeatable. The measuring system is also immune to external influences such as wind, vibration, and physical contact with the housing, leading to simple installation requirements and high reliability. The system is completely dust-tight and is virtually maintenance-free.

Figure 4a: Coriolis feeding system with feed screws for additives

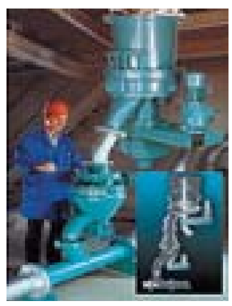
Practical applications

Coriolis measuring systems have been successfully applied to the feeding of pulverised coal and petcoke to cement kiln burners, feeding additives and dusts to cement mills, and measuring, feeding, and blending at load-out stations. The technology can be applied to almost all kinds of pulverised materials, dusts, meals, and granules including cement, fly ash, filter dust, lime powders and hydrates, pulverised coal and petcoke, ground slag, silica, and marl. Present designs can handle feed rates between 0.5 to up to 300tph.

Continuous flow rate measurement

The Coriolis mass flow meter can be installed in a material flow path to continuously measure flow of a dry bulk solid. A typical installation would be between the outlet of a storage silo and the inlet of a blender, mixer or mill. The Coriolis meter can continuously indicate the instantaneous material flow rate, monitor a process, and trigger alarms such as min /max flow rate and deviation. Other feeders can be slaved to the mass flow meter to realize proportional additive (master/slave) control and blending.

Figure 4b: Coriolis coal feed system with horizontal star feeder



Totalling and batch control

The Coriolis mass flow meter can be utilised to total material flows for batch control and load-out applications. Figure 4c shows a Coriolis mass flow meter used at a load-out blending station. A loss-in-weight feeder is also used in this application to portion a minor ingredient.

As a side benefit, the Coriolis meter provides excellent homogenisation of the two materials.

Continuous feeding and blending

Combined with a suitable variable-speed pre-feeding device (such as a screw feeder, rotary feeder, position-controlled feeder, or horizontal star feeder – see Figure 3), the Coriolis mass flow meter can also be used as a precise mass flow feeding system. In this application, the flow rate measured by the meter is compared to a demand set point, and a variable speed pre-feed device is continuously adjusted to match the demand. By separating the pre-feed and measuring devices, the optimum feeding device can be selected for the specific material. Figure 4a shows a Coriolis mass flow feeding system with an inclined screw feeding an additive to a cement process. Figure 4b shows a Coriolis mass

Figure 4c: Coriolis loading station

flow feeding system with a horizontal star feeder feeding pulverised coal to a cement kiln burner.

Accuracy of the Coriolis mass flow meter

Typical accuracies of the Coriolis mass flow meter are better than +/- 0.5 per cent of the actual feed rate over a defined measuring range. The following tests results show actual performance of the Coriolis system in the laboratory and in the field.

Figure 7a: pulverised fuel feeding data – short-term accuracy

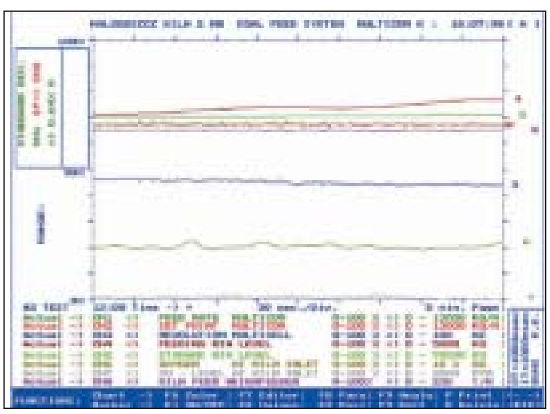
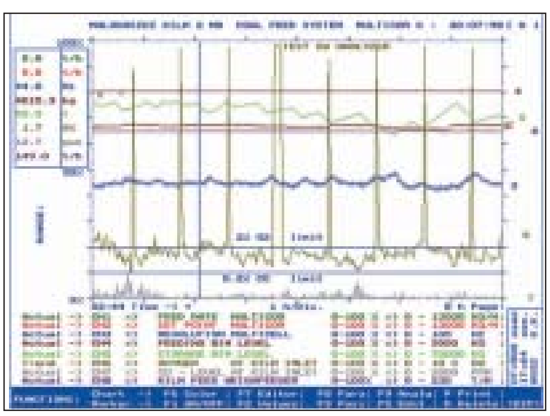


Figure 7b: pulverised fuel feeding data – long-term performance



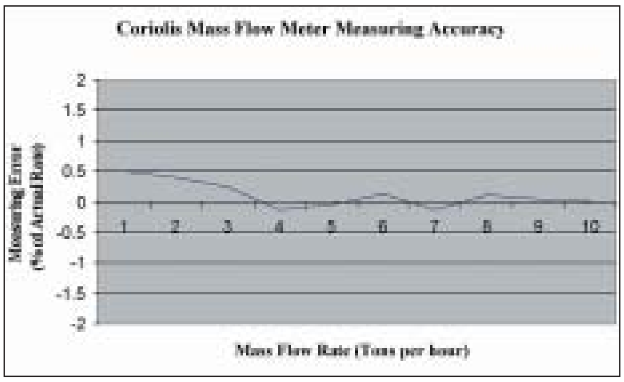


Figure 5: Coriolis flow accuracy

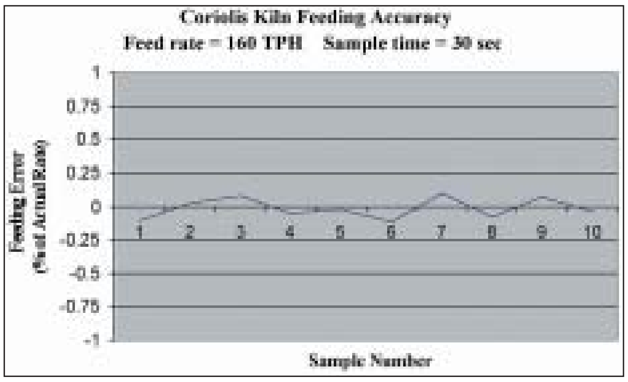


Figure 6: Coriolis kiln feed accuracy

Laboratory test results

Accuracy of the Coriolis mass flow meter can be determined in the laboratory be either pre-weighing (feed bin on load cells) or post-weighing material (gain-in-weight check scale). Accuracy test results[2] using dry quartz sand are shown in Figure 5 that plots the error in the mass flow measurement (per cent of the actual flow rate) versus the actual flow rate in the range of 1-10tph. As can be seen, the accuracy of the Coriolis meter is better than 0.5 per cent of the actual flow rate, and the percentage error diminishes as flow rates are increased.

Field test results

Kiln feeding

Accurate kiln feeding is essential to produce consistent high quality clinker. Figure 6 shows the error in feed rate calculated from 10 consecutive 30-second samples observed on a Coriolis kiln feeding system running at 160tph. The standard deviation of these consecutive samples is less than 0.2 per cent thus achieving the desired goal of +/- 0.5 per cent.

Pulverised fuel feeding system

Short-term pulverised fuel feeding accuracy is critical for the economical and ecological operation of a cement kiln and for the production of high quality cement. Figure 7a shows the feed rate of a Coriolis mass flow pulverised fuel feeding system compared to the plant set point over a five-minute period. A total of 300 samples are included at one-second intervals. Statistical analysis of this data shows that the standard deviation of samples is less than 0.45 per cent resulting in extremely high short-term feeding consistency of the fuel.

Figure 7b shows long-term kiln performance over an eight hour period. As can be seen, the level of the material feed bin does not influence the accuracy of the feeding system. Even at O_2 levels below two per cent at the kiln inlet, the CO level does not exceed 0.2 per cent.

Conclusion

The Coriolis measuring principle has been successfully applied to provide accurate measurement and feed rate control of pulverised coal, petcoke, kiln feed, fly ash, and many other bulk solids in cement process applications.

The Coriolis flow meter is a direct mass flow measuring device that is not influenced by variations in material properties or outside forces. It can be used for continuous flow rate measurement, totalling, batch control, and continuous feeding. It is simple to install, reliable, and virtually maintenance-free.

References

1. Boyle, Kevin C: *Mass-flow meter: Measuring material flow rates the gravimetric way*, Powder and Bulk Engineering, February 1996.

2. Tests conducted at Schenck Process, Darmstadt, Germany. Contact the author for more information about the test set-up and results.